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Emotional face processing and attention performance in three domains: Neurophysiological mechanisms and moderating effects of trait anxiety

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Abstract

The rapid processing of emotional information adaptively regulates the allocation of attention, but may also divert resources away from attention performance, particularly for those showing elevated anxiety. The temporal organization of rapid emotional processing and its implications for attention performance, however, remain unclear. Participants were 18 healthy adults (12 females) who reported on trait anxiety. Tasks-irrelevant fearful, sad, and neutral faces were presented for 50 ms prior to each trial of a cued attention task measuring alerting, orienting, and executive attention. Electroencephalographic recordings were made from 64 scalp electrodes to generate event-related potentials (ERPs) to faces. Emotional face type and trait anxiety modulated ERP responses at three early stages around 200 ms, 250 ms, and 320 ms. Although behavioral findings showed enhanced orienting and executive attention following presentation of fearful and sad faces, the degree to which these faces modulated ERP responses, particularly around 250 ms, interfered with orienting and executive attention in the high trait anxiety group, and enhanced alerting in the low trait anxiety group. Results are discussed in terms of mechanisms in the emotional capture of attention and implications for understanding attentional processes in anxiety.

Keywords: Emotional face processing; ERPs; Emotion-attention interactions; Trait anxiety

Rapid and accurate detection of negative emotional information is highly adaptive because it provides critical information about potential danger in the environment. In this way, emotional processes regulate the allocation of attention by highlighting relevant information and inhibiting irrelevant information. On the other hand, preferential attention towards negative information is implicated in the etiology and course of anxiety and mood disorders (Beck and Clark, 1997; Compton, 2003; Derryberry and Reed, 2002). Studies using scalp-recorded event-related potentials (ERPs) are able to explore the time course of the emotional capture of attention at a very high temporal resolution. Links between early stages of emotional processing and attention performance, however, are poorly understood.

The emotional face processing literature provides important information about rapid and automatic stages of emotional processing (Eimer and Holmes, 2002; Pizzagalli et al., 1999; Righart and de Gelder, 2006; Sato et al., 2001). Negative emotional faces are preferentially processed: As early as 80–100 ms, negative emotional faces compared to neutral faces elicit enhanced ERP activity (Eger et al., 2003; Smith et al., 2003) and modulate later stages of ERP responses between 200 and 300 ms (Campanella et al., 2002; Smith et al., 2003; Taylor et al., 2004). For example, posterior P200 (Carretié et al., 2001; Correll et al., 2006; Eimer et al., 2003) and P300 amplitudes, thought to reflect emotional salience processing, are greater for negative emotional faces and pictures (Cuthbert et al., 2000; Dien et al., 2004). Negative-going waveforms are also greater within 300 ms following presentation of negative versus positive faces and liked versus disliked faces (Pizzagalli et al., 1999; Pollak and Tolley-Schell, 2003; Schupp et al., 2003). In particular, a posterior face-specific component, N170, is modulated by emotion (Batty and Taylor, 2003; Eger et al., 2003; Pizzagalli et al., 1999), and is greater in the right hemisphere (Bentin et al., 1996). Other studies, however, have failed to find enhanced N170 amplitudes for negative emotional faces (Eimer and Holmes, 2002), and suggest that later

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occurring components are sensitive both to faces and emotional valence (Sato et al., 2001; Taylor et al., 2004). For example, in a passive viewing task, posterior N270 amplitudes were greater for emotional versus neutral faces (Sato et al., 2001).

If, instead, faces are irrelevant to performing a target task, ERP responses related to the control and inhibition of attention may emerge (Hanoch and Vitouch, 2004; Kliegel et al., 2003; Rokke et al., 2002). The N200 response, for example refers to activity over frontal midline regions 200 to 350 ms post stimulus onset, and is generated by frontal structures related to cognitive control, such as the anterior cingulate cortex. (Nieuwenhuis et al., 2003). The N200 is thought to reflect conflict monitoring and the gating of incoming information to the prefrontal cortex, thus signaling the extent to which attentional control is required. Emotional information and states are thought to bias the competition for cognitive control and processing resources measured by N200. For example, N200 amplitudes are greater following fearful, sad, and angry compared to neutral facial expressions (Campanella et al., 2002; Schutter et al., 2004) and other frontally-generated components, such as those related to error monitoring, are enhanced among individuals showing high negative affectivity (Luu et al., 2000a,b). Most ERP studies of emotional faces, however, employ passive viewing and other tasks which are unlikely to recruit cognitive control.

Studies of emotional face processing rarely relate ERPs directly to attention performance. This is surprising given that the excellent temporal resolution of ERPs provides a tool for disentangling links between attentional processing operations and attention performance (Smith et al., 2003). Behavioral studies suggest that viewing negative emotional faces can both interfere with (Eastwood et al., 2003) and facilitate (Ladouceur et al., 2006) attention performance. In a study of fearful face processing among autistic children, activity related to visual processing (N300) but not the face-specific N170, was linked to enhanced attention performance in social and joint attention tasks (Dawson et al., 2004). In other ERP research, affective processing (e.g., P200) was associated with the speed of responding in a stereotype assessment paradigm (Correll et al., 2006). Few studies, however, clarify mechanisms in the emotional capture of attention that impact multiple domains of attention performance.

Assessing the emotional capture of attention in relation to attention performance is especially relevant to understanding the interplay between anxiety and attention. Anxiety is associated with enhanced attention to threat-related stimuli such as fearful faces; but this has been found to have a negative impact on attention performance reflecting spatial orienting and top-down executive control of attention (Eastwood et al., 2003; Fenske and Eastwood, 2003; Fox et al., 2001; Mogg et al., 1992; Schupp et al., 2003). Like negative emotional information, anxious states are thought to rapidly and automatically bias the allocation of processing resources so that when there is competition for attention, emotional processing is prioritized over attention performance (Easterbrook, 1959; Hanoch and Vitouch, 2004; Leith and Baumeister, 1996; Meinhardt and Pekrun, 2003). Anxiety within an optimal range would show fewer biasing effects and might actually enhance attention performance (Gray, 2004).

Taken together, these findings highlight a critical goal in the study of emotional face processing, anxiety, and attention: determining the impact of very early stages of emotional face processing on attention in multiple domains of attention (Fan et al., 2002; Posner and Petersen, 1990). Chronometric analyses of separable attention capacities, alerting, orienting, and executive attention, have been combined into a single assessment with fully randomized conditions within blocks called the Attention Network Test (Fan et al., 2003, 2002). In this study, we modified this task in a novel way: each trial was preceded by task-irrelevant fearful, sad, and neutral faces. This design allowed us to assess the impact of emotional face processing on alerting, orienting, and executive attention when faces also recruit attentional control and inhibition because they are distracters.

In the present study, we examined whether emotional factors would bolster relatively early and automatic stages of emotional face processing (0–400 ms), and whether these rapid ERP responses would be related to subsequent attention performance. We hypothesized that ERP responses would be enhanced following negative versus neutral faces and in those showing relatively high versus low trait anxiety. We also hypothesized that links between these ERPs and attention performance would be moderated by trait anxiety. For those showing relatively high trait anxiety, enhanced emotional processing would interfere with attention, particularly orienting and executive attention, whereas among those showing relatively low trait anxiety, enhanced emotional processing would bolster attention, particularly alerting.

1. Methods

1.1. Participants

Participants were 28 adults between the ages of 19 and 34 (25 females) recruited through the psychology participant research pool at an urban college in the Northeast, and screened for identified psychological or neurological impairments. The data from 10 subjects were excluded due to experimental problems: specifically, excessive EEG artifacts (5) and performance errors on greater than 25% of trials, indicating poor engagement with the task (5). This left a total sample of 18 (13 females). This high rate of exclusion was necessary in order to retain only those participants who complied with task directions. Self-reported race/ethnicity was as follows: 6 Caucasian, 1 African American, 4 Hispanic, 5 Asian, 2 "Other."

1.2. Procedures and measures

Participants completed the State Trait Anxiety Inventory (STAI; Spielberger, 1983) immediately after consent procedures in order to assess trait anxiety[1]. Participants were

[1] State anxiety was also assessed at baseline and four additional times following each block of the attention task; baseline and subsequent assessments did not significantly differ suggesting that the task did not induce or modulate anxious mood. There was a high correlation between state and trait anxiety ($r=.72$, $p<.001$). Because we were interested in trait tendencies to experience anxious arousal, however, we did not co-vary out state anxiety because this might have inaccurately reduced effects.